Digital Cavity Resonance Monitor – alternative method of measuring cavity microphonics.*

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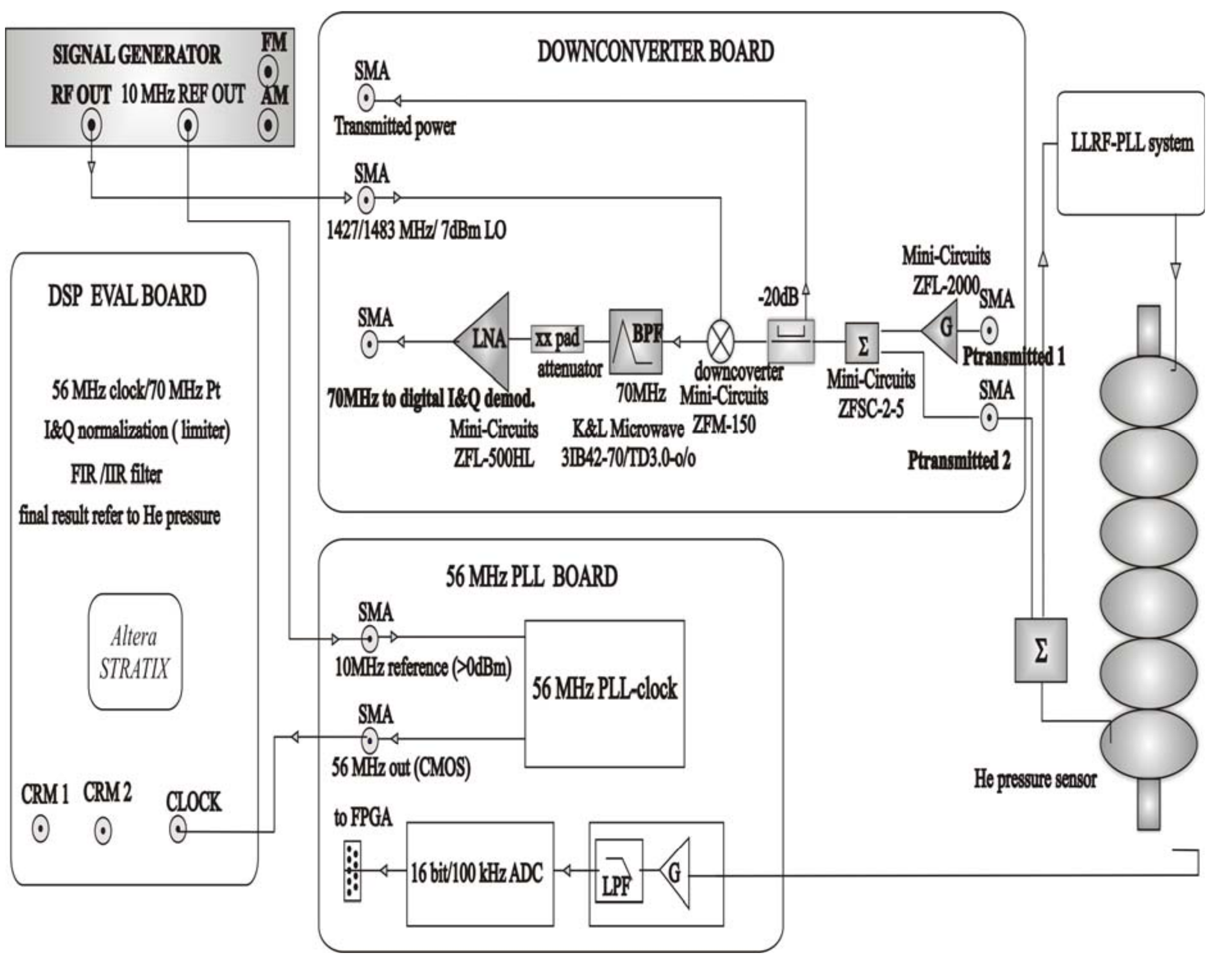
Abstract

As is well known, mechanical vibration or microphonics in a cryomodule causes the cavity resonance frequency to change at the vibration frequency. One way to measure the cavity microphonics is to drive the cavity with a Phase Locked Loop (PLL). Measurement of the instantaneous frequency or PLL error signal provides information about the cavity microphonic frequencies. Although the PLL error signal is available directly, precision frequency measurements require additional instrumentation, a Cavity Resonance Monitor – CRM. The analog version of such a device has been successfully used for several cavity tests [1]. In this paper we present a prototype of a Digital Cavity Resonance Monitor designed and built in the last year. The hardware of this instrument consists of an RF downconverter, digital quadrature demodulator and digital processor motherboard (Altera FPGA). The motherboard processes received data and computes frequency changes with a resolution of 0.2 Hz, with a 3 kHz output bandwidth. The results are available in both analog and digital format.

FUNCTIONAL BLOCK DIAGRAM



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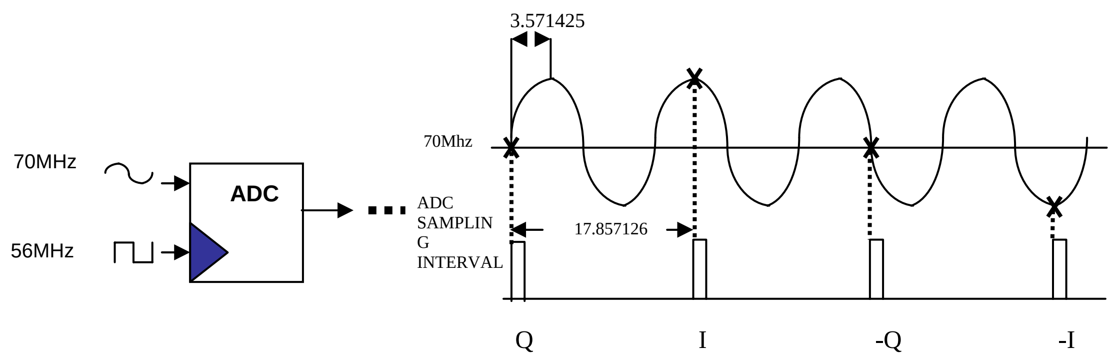
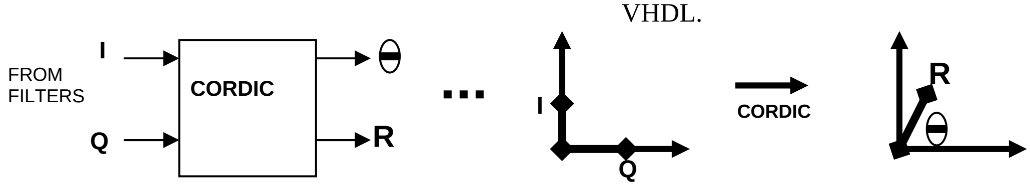
We are using digital quadrature detection of a 1497 MHz cavity probe signal, downconverted to 70 or 14 MHz, then sampled at 56 MHz. In either case, I and Q are the result of sampling, however sampling 14 MHz signal instead of 70 MHz provides a better SNR (signal to noise ratio) according to the following formula : SNR=-20log(2*pi*f*t_{jitter})dB [2] , where ft is cavity signal and t_{jitter} is a clock jitter. Digital signal processing of I and Q is shown below. The final result is detuning angle and frequency.

DIGITAL SIGNAL PROCESSING

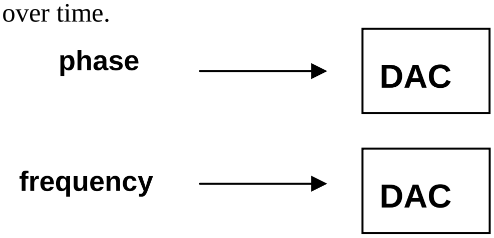


70 MHz signal is phase locked to 56MHz clock. 70 MHz IF analog signal is converted to digital data with 12 bit Analog to Digital Converter (ADC) at 56 MHz rate.

Consecutive samples are orthogonal and assigned Q, I,-Q, and –I.
The sampled signals are digital processed inside Altera FPGA. The processing code is written in VHDL.



CORDIC (**CO**ordinate **R**otation **DI**gital **C**omputer) transforms rectangular I and Q components to phase and magnitude
CORDIC calculates the trigonometric functions of sine, cosine, magnitude and phase (arctangent) to any desired precision.
CORDIC minimizes the size of FPGA needed to perform the calculation. The algorithm involves only shift and add.
Frequency is the rate of change of phase over time.

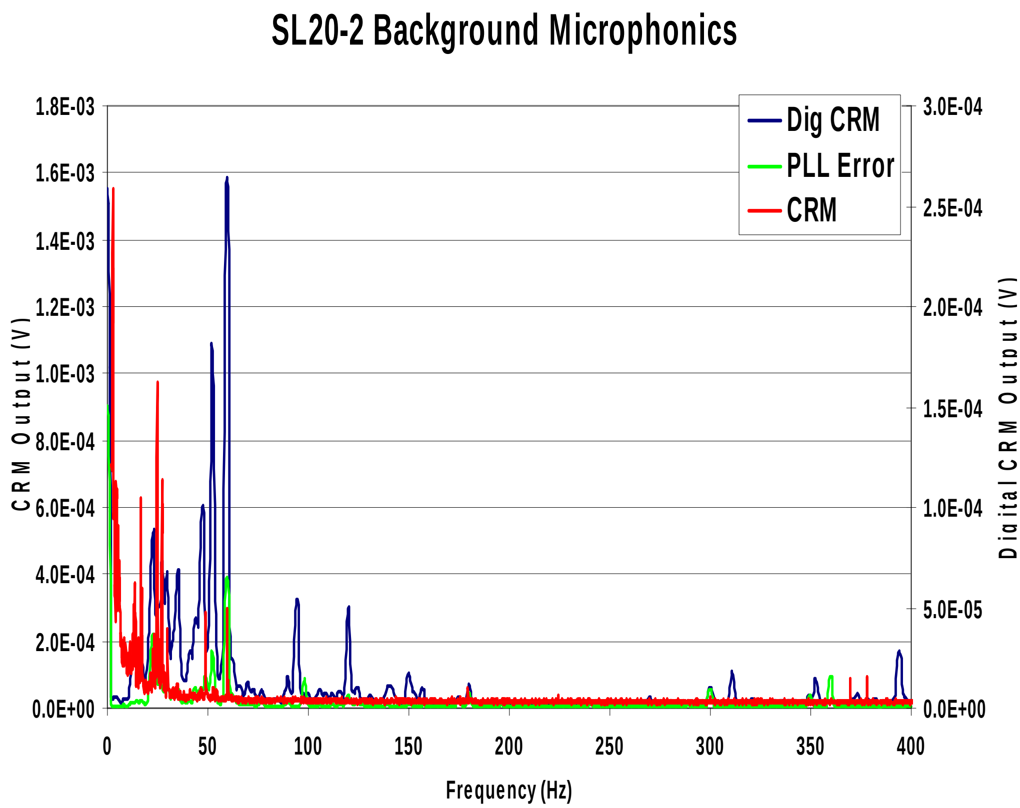


Phase and Frequency information are output to 18 bit Digital To Analog converters (DAC)

Phase change is the difference between two consecutive phases
Time is programmed for the frequency range specification.
For a given dT, the further the IF frequency is from 70 MHz, the larger the voltage value.
Voltage values are positive for IF frequencies greater than 70 MHz and negative for IF frequencies smaller than 70 MHz.

Frequency resolution = Frequency Range / 2^18
dT = 1/Frequency resolution

RESULT



The digital system was used to measure microphonic frequencies of an operating CEBAF SRF cavity. The results are compared here to an existing analog measurement system, and to a measurement of the PLL error signal. Since the measurements were not taken simultaneously, stochastic components differ between the measurements, but spectral peaks coincide at several known invariant lines (e.g. 27, 30, 59.5). Further tests of the improved instrument are planned.

CONCLUSION

The prototype system was successfully tested with two different type of SC cavities : newer 7-cells installed in the FEL, and 5-cell cavities installed in CEBAF's South Linac. It is planned to use different RF components and digital-to-analog converters to achieve wider dynamic and frequency range.

ACKNOWLEDGMENT

Thanks to Curtis Cox at Jefferson Lab for fabrication of the Digital Cavity Resonance Monitor chassis.

REFERENCES

[1] - MICROPHONICS TESTING OF THE CEBAF UPGRADE 7-CELL CAVITY
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[2] – UNDERSTAND THE EFFECTS OF CLOCK JITTER AND PHASE NOISE ON SAMPLED SYSTEMS
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